Evaluation of Chemical Structures and Work Function of Nickel Silicide near the Interface between Nickel Silicide and SiO_2

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Outline

1. Introduction
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    - Evaluation of Work Function of Ni-Silicides
4. Summary

Sub-50nm CMOS Technologies

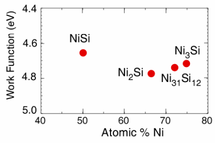
Practical Limitations of Poly-Si Gate

- Gate Leakage Current Flowing Through Gate Resistance
- Poly-Si Depletion Effect

Silicide Gate, Metal Gate (Ni-Silicide, TiN, etc...)

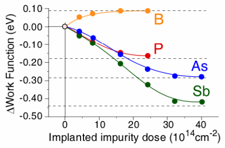
☆ **Ni-Silicide**

Transformation of Chemical Composition and Crystalilne Phase



J. A. Kittl et al., IEEE ELECTRON DEVICE LETTERS (2006)

Impurity Incorporation

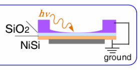


J, Kedzierski et al., IEEE Trans. Electron Device, 52(2005), p39

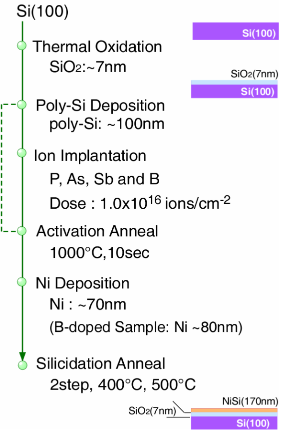
☆ Quantitative understanding on the mechanism to define the effective work function of Ni-silicide has not been confirmed yet

This Work

Evaluation of the Work Function of Ni-silicide and the Checmial Structure near the Ni-Silicide/SiO_2 Interface from the SiO_2 Side



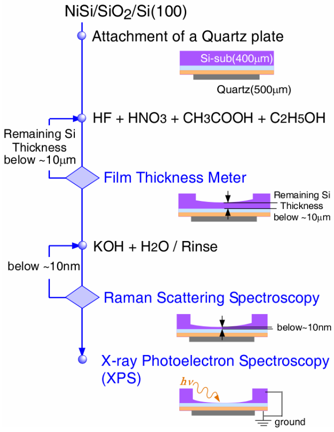
Sample Preparation



Si(100)

- Thermal Oxidation
  SiO_2:~7nm
- Poly-Si Deposition
  poly-Si: ~100nm
- Ion Implantation
  P, As, Sb and B
  Dose : 1.0×10^{16} ions/cm^{-2}
- Activation Anneal
  1000°C,10sec
- Ni Deposition
  Ni : ~70nm
  (B-doped Sample: Ni ~80nm)
- Silicidation Anneal
  2step, 400°C, 500°C

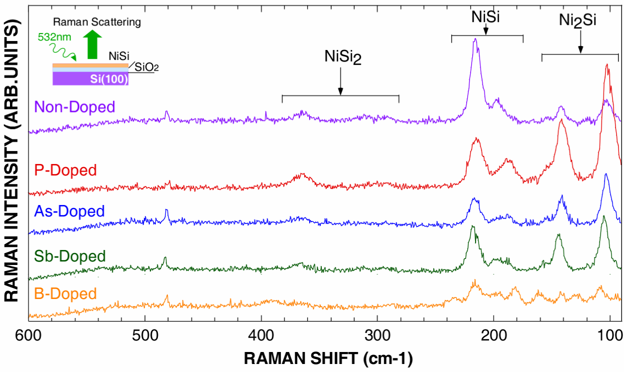
Back Side Etching



$NiSi/SiO_2/Si(100)$

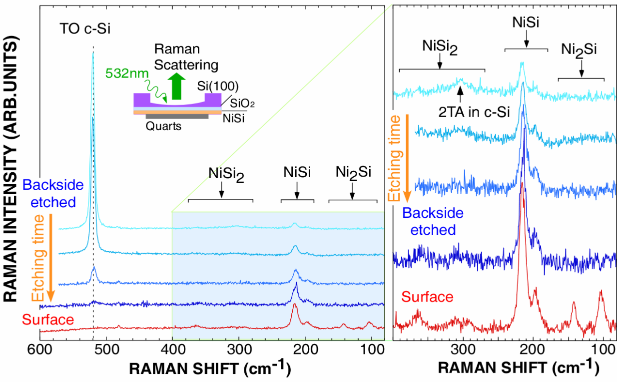
- Attachment of a Quartz plate
- $HF + HNO_3 + CH_3COOH + C_2H_5OH$
- Film Thickness Meter
- $KOH + H_2O$ / Rinse
- Raman Scattering Spectroscopy
- X-ray Photoelectron Spectroscopy (XPS)

Raman Scattering Spectra for non-doped and Impurity Implanted Ni-Silicide



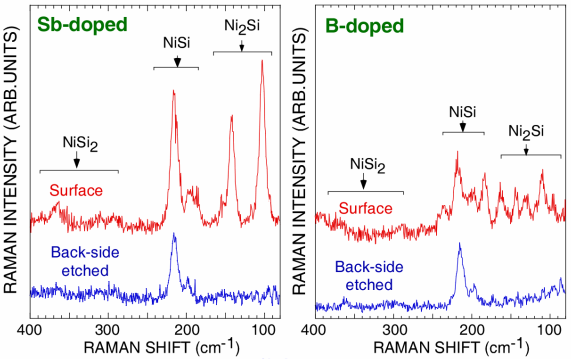
- **The silicidation is strongly affected by impurity incorporation.**

Raman Scattering Spectra for non-doped Ni-silicide at Each Step of Back-side Etching



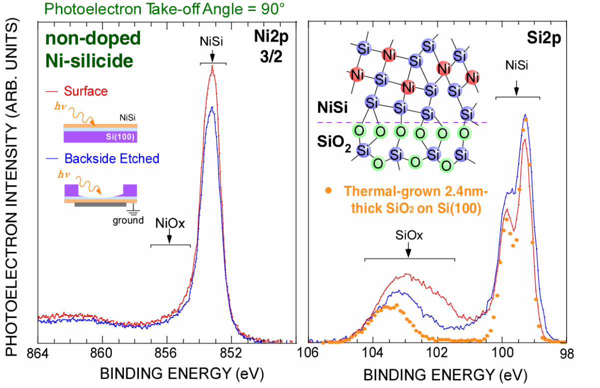
- **In the region near the Ni-silicide/SiO_2 interface, the Ni mono silicide phase is dominant.**

Raman Scattering Spectra for Sb and B-doped Ni-silicide Measured from Ni-silicide Surface and Back-side



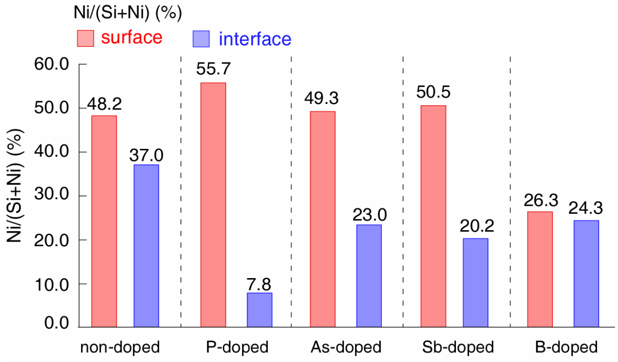
- **In the region near the Ni-silicide/SiO_2 interface, the Ni-rich silicide phase is hardly observed and mono silicide phase is dominant as in the case of non-doped Ni-silicide.**

Chemical Bonding Features near the Ni-silicide/SiO2 Interface and near the Ni-silicide Surface



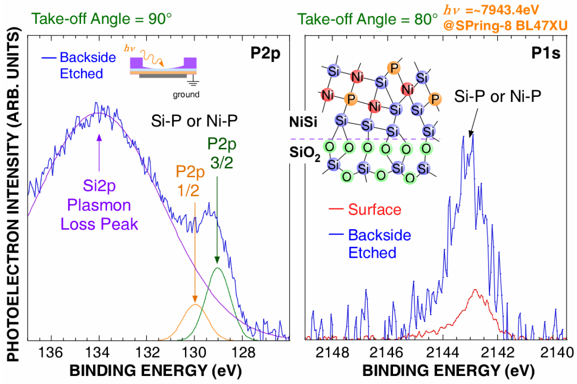
- The chemical bonding features near the Ni-silicide/SiO2 interface mainly consist of Si-O bonding units.

Average Ni Compositions of Ni-silicide near the Surface and the Ni-silicide/SiO2 Interface



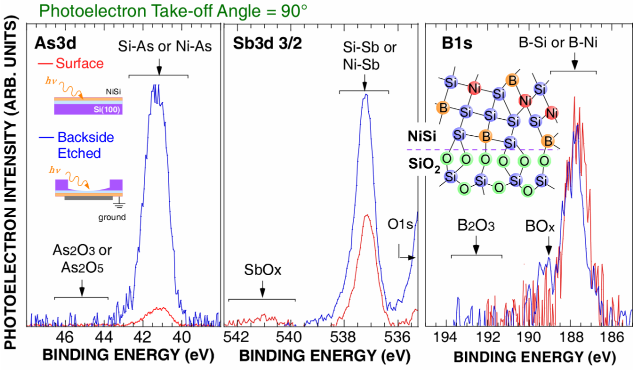
- The average Ni/(Ni+Si) content near the Ni-silicide/SiO2 interface is Si-rich.

P2p and P1s Spectra for the P-doped Ni-silicide Measured from the Surface and the Back-side



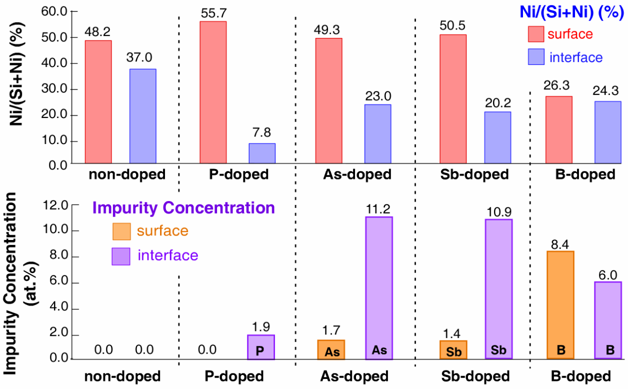
- No incorporation of P atom into the thermally-grown SiO2 layer, but P atom pile-up near the interface is confirmed.

As3d, Sb3d 3/2 and B1s Spectra for Impurity Implanted Ni-silicides Measured from the Surface and the Back-side



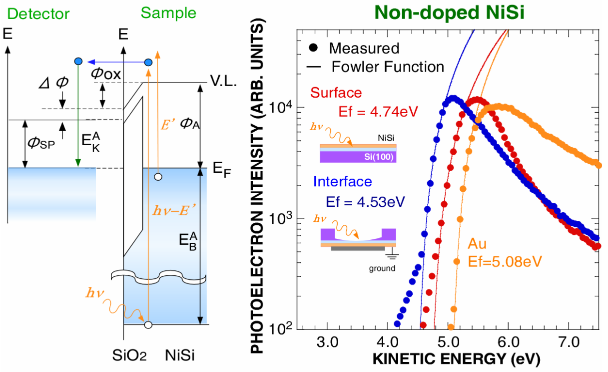
- Near the Ni-silicide/SiO2 interface, the signal of implanted impurity atoms bonded with Ni and/or Si atoms are clearly observed and, for the B-doped Ni-silicide, B-O bonding units are slightly observed .

Average Chemical Compotion for Ni-silicide at the surface and the Ni-silicide/SiO2 Interface



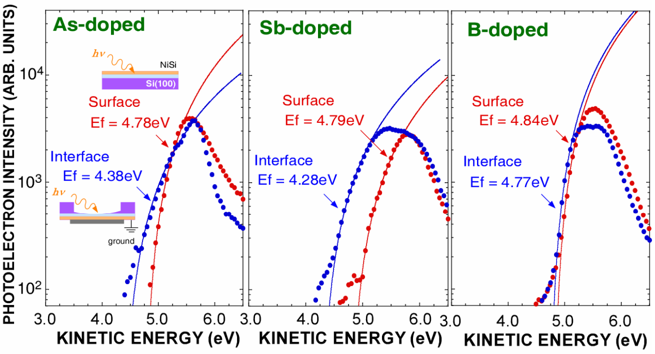
- For all the samples, implanted impurities are piled up near the interface.

Determination of Work Function for non-doped Ni-Silicide



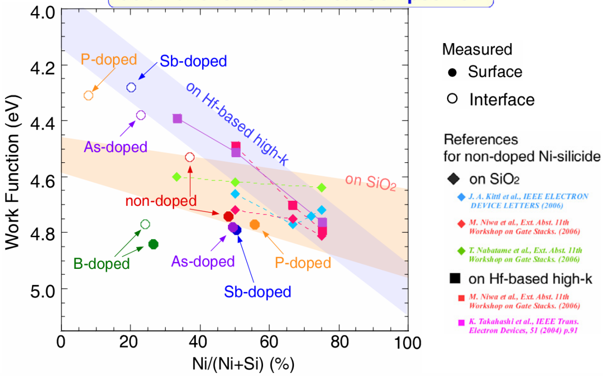
- The work function near non-doped Ni-silicide/SiO2 interface is determined to be ~4.53eV and this value is about ~0.2eV lower than that in Ni-silicide surface (4.74eV).

Determination of Work Function for Impurity Implanted Ni-Silicide



- **For the cases doped with group V impurities, the work function near the interface is significantly decreased in comparison to the value in the surface.**
- **For the B doped Ni-silicide, almost the same work function value is obtained both in the surface and near the interface.**

Work Function of Ni-Silicide as a Function of Chemical Composition



- **For the samples doped with group V impurities, the reduction of the work function is thought to be mainly due to the reduction of Ni composition.**
- **For the B doped Ni-silicide, B incorporation suppresses a reduction in the work function with a decrease in Ni composition.**

Summary

Chemical Bonding Features near Ni-Silicide/SiO_2 Interface

- The Ni mono-silicide phase is dominant and average chemical composition is Si-rich as compared with Ni-silicide surface. And, Si-O bonding units are mainly formed at the interface between Ni-silicide and SiO_2.
- For all the cases, implanted impurities are piled up near the interface and impurity atoms bonded with Ni and/or Si atoms are dominant, but in the case of B-doped Ni-silicide, B-O bonding units are slightly observed.

Effective Work Function of Ni-Silicide

- For the cases doped with group V impurities such as P, As and Sb, the Ni composition rather than P, As and Sb pile-ups is a major factor to change the effective work function, while for B-doped Ni-silicide, the B incorporation suppresses a reduction in the work function with a decrease in the Ni composition.

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